

# An identification key to species in the *mali* complex of *Aphelinus* (Hymenoptera, Chalcidoidea) with descriptions of three new species

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Academic editor: M. Yoder | Received 21 December 2011 | Accepted 21 April 2012 | Published 28 May 2012

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[urn:lsid:zoobank.org:pub:88F262E0-6354-46B5-8599-FFFA5B1875A6](https://zoobank.org/pub:88F262E0-6354-46B5-8599-FFFA5B1875A6)

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**Citation:** Hopper KR, Woolley JB, Hoelmer K, Wu K, Qiao G-X, Lee S (2012) An identification key to species in the *mali* complex of *Aphelinus* (Hymenoptera, Chalcidoidea) with descriptions of three new species. Journal of Hymenoptera Research 26: 73–96. doi: 10.3897/JHR.26.2584

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## Abstract

The *Aphelinus mali* complex consists of eleven described species. Monophyly of this complex is well supported by a combination of traits: (1) a single complete row of setae proximal to the linea calva of the fore wing, with a few additional setae in the angle between this row and the marginal vein; (2) linea calva open (no setae at its posterior edge); (3) head and body dark except for parts of the metasoma; (4) meso- and metacoxae dark; (5) metafemur pale, (6) metatibia dark. Species within the complex have been distinguished by color and shape of antennal segments (particularly the third funicular segment), color of legs and metasoma, and relative length of ovipositor versus mesotibia. We provide a key for identifying species in the *mali* complex, and describe three new species, *Aphelinus glycinis* **sp. n.**, *Aphelinus rhamni* **sp. n.**, and *Aphelinus coreae* **sp. n.** from material in laboratory cultures originally reared from soybean aphid in China and Korea as candidates for biological control of soybean aphid, *Aphis glycines*.



**Keywords**

cryptic species, taxonomy, biological control

**Introduction**

The genus *Aphelinus* (Hymenoptera: Aphelinidae) comprises 84 recognized species (Noyes 2011), all of which are internal parasitoids of aphids. There are several complexes of closely related species in the genus, and identification of species within these complexes has been problematic (Heraty et al. 2007), leading to a confused literature on host specificity. The *Aphelinus mali* complex comprises 11 described species (Ashmead 1888; Evans et al. 1995; Gahan 1924; Girault 1913; Haldeman 1851; Hayat 1998; Prinsloo and Naser 1994; Timberlake 1924; Yasnosh 1963; Zehavi and Rosen 1988), and there are 6 other closely related species (Carver 1980; Hayat 1998; Howard 1917; Kurdjumov 1913; Walker 1839; Yasnosh 1963) that differ from the members of the complex in one or two traits (Table 1). The species within the complex have diverged little in morphology so the taxonomy within the complex has been confused, and many specimens have been identified as *A. mali* (Haldemann) or *A. gossypii* Timberlake that are likely different species based on differences in the aphid host species and geographical regions from which they were collected. We provide a key to identification of species in the *A. mali* complex based on 19 traits coded primarily from species descriptions. We describe three new species that were collected in China and Korea during exploration for natural enemies of the soybean aphid, *Aphis glycines* Matsumura, all of which are candidates for biological control of this important pest.

The genus *Aphelinus* consists of several complexes of cryptic species including the *mali* complex, the *varipes* complex (Heraty et al. 2007), the *asychis* complex (Kazmer et al. 1995, 1996), the *perpallidus* complex (unpublished data), and possibly others. Cryptic species are closely related species that differ little in the morphological features used for taxonomy, but differ critically in physiological, behavioral and ecological traits, such as climatic adaptation and host range (Darling and Werren 1990; DeBach 1969). Recent evidence from molecular studies suggests that cryptic species of hymenopteran parasitoids may be far more common than previously realized (Campbell et al. 1993; Clarke and Walter 1995; Darling and Werren 1990; Kankare et al. 2005a; Kankare et al. 2005b; Kazmer et al. 1996; Molbo et al. 2003; Rincon et al. 2006; Stouthamer et al. 2000; Stouthamer et al. 1999). The success of biological control programs depends on accurate species-level identifications of hosts and natural enemies, but choosing the best parasitoids for biological control programs is complicated by cryptic species (Rosen 1986; Wharton et al. 1990). Because cryptic species are difficult to recognize, studies on host ranges of parasitoids have often confounded more than one parasitoid species (Clarke and Walter 1995; Hopper et al. 1993), making analysis and prediction of host range difficult. Heightened concern about potential impacts of introduced parasitoids on non-target species makes accurate prediction of host range crucial to biological control introductions.



**Table 1.** Species in *Aphelinus mali* complex and related species

Group	Species	Original description
<i>mali</i> complex	<i>basilicus</i>	Hayat 1998
	<i>campestris</i>	Yasnosh 1963
	<i>coreae</i> sp. n. <sup>1</sup>	
	<i>engaeus</i>	Prinsloo and Naser 1994
	<i>ficusae</i>	Prinsloo and Naser 1994
	<i>glycinis</i> sp. n. <sup>1</sup>	
	<i>gossypii</i>	Timberlake 1924
	<i>mali</i>	Haldeman 1851
	<i>niger</i> <sup>2</sup>	Girault 1913
	<i>paramali</i>	Zehavi & Rosen 1989
	<i>rhamni</i> sp. n. <sup>1</sup>	
	<i>sanborniae</i>	Gahan 1924
	<i>siphonophorae</i> <sup>2</sup>	Ashmead 1888
	<i>spiraecolae</i>	Evans et al. 1995
related species	<i>chaonia</i> <sup>3</sup>	Walker 1839
	<i>prociphili</i> <sup>3</sup>	Carver 1980
	<i>sharpae</i> <sup>3</sup>	Hayat 1998
	<i>brunneus</i> <sup>4</sup>	Yasnosh 1963
	<i>daucicola</i> <sup>4</sup>	Kurdjumov 1913
	<i>lapisligni</i> <sup>4</sup>	Howard 1917

1 new species described in this paper  
2 insufficient description to be included in tree or key  
3 difference from *mali* complex: more than 1 line of setae in delta region  
4 difference from *mali* complex: posterior femur dark

Methods

Three new species in the *A. mali* complex were collected from *Aphis glycines* in the Peoples Republic of China near Beijing and Xiuyan (Liaoning Province) and in the Republic of South Korea near Miryang (Gyeongsangnam Province) and maintained as laboratory cultures at the Beneficial Insects Introduction Research Unit, USDA-ARS, Newark, DE. All of the specimens described below were taken from lab cul- tures, killed in 95% ethanol, and most were critical-point-dried and card-mounted. Selected specimens were then slide-mounted in Canada balsam. Specimens pho- tographed for coloration (Figs 1–6,15–20, and 29–34) were killed in ethanol and photographed as soon as possible, by placing specimens on a layer of KY® jelly in a small watch glass, submerging the specimen in ethanol, and photographing using a Leica MZ 16 stereomicroscope, fiber optic illumination, a Zeiss Axiomat MRc5 camera, and Helicon Pro image-stacking software. Slide-mounted specimens were photographed using differential interference contrast optics (DIC) with an Olympus BH2 compound microscope, and the same camera and software. Final modifications to images were made using Adobe Photoshop, Adobe Lightroom, and Adobe InDe-



sign. Type material and other specimens examined have been deposited as indicated in the species descriptions. The label data for each specimen has been digitized and all specimens bear individual accession numbers for Texas A&M University Insect Collection (e.g. TAMU x0616203), as well as a machine-readable bar-code. In the verbatim label data provided for holotypes, a single | symbol indicates a new line on a label, and the || symbol indicates a second or third label. Vouchers are maintained at -20°C in molecular grade ethanol at the Beneficial Insect Introduction Research Unit, Newark, Delaware, and at the Department of Entomology, Texas A&M University, College Station, Texas.

We tabulated and coded 19 traits for species in the *A. mali* complex, using the original species descriptions for the most part. These traits included color of scape, pedicel, club, coxae, femora, tibiae, tarsi, and metasoma, as well as shape of third funicle and club (length:width) and length of ovipositor relative to mesotibia. For some traits, males and females differed (e.g., F3 shape, procoxae color) and the values were scored separately. When trait data were lacking from original descriptions, we used data from later descriptions. Trait values for the new species in the complex were taken from specimens freshly killed in ethanol and slide-mounted specimens. These traits were used to construct an on-line, interactive, multiple entry identification key to the *mali* complex which is available on request. Of the 19 traits, 12 proved to be most consistent and useful in distinguishing species, and these are presented in Table 2.

Table 3 is a list of anatomical terms used in the paper followed by URI values (uniform resource identifiers), that will link the terms to precise definitions and illustrations in the Hymenoptera Anatomy Ontology project (see <http://portal.hymao.org> and <http://hymao.org> for more information on this initiative). Additional information on morphological terminology in Chalcidoidea is available in Gibson (1997) and <http://www.canacoll.org/Hym/Staff/Gibson/apss/chglintr.htm>.

The ventral surface of the antennal scape refers to the surface that is ventral when the antennae are deployed, or anterior when the antennae are folded on the face. F1, F2 and F3 refer to the first, second and third segments of the funicle of the antennal flagellum, respectively. T1, T2 etc. refer to metasomal terga. We use the term ovipositor to refer to the anatomical cluster consisting of the first valvula, second valvula, third valvula, first valvifer and second valvifer. Length of the ovipositor is the measurement (generally of a slide-mounted specimen) from the anterior margin of the second valvifer to the posterior (distal) end of the third valvula.

Measurements were made with an eyepiece reticle in a Leica MZ16 microscope or Zeiss standard 16 compound microscope, or from digital images captured using the methods described above. As with any species of *Aphelinus*, users will require series of high quality specimens, both male and female, and both card- or point-mounted and slide-mounted specimens, to obtain confident identifications. Noyes (1982) remains the best guide to techniques for preparing specimens of Chalcidoidea, and we have largely followed his recommendations for card-mounting and slide-mounting specimens.



**Table 2.** Traits coded for species in *mali* complex of *Aphelinus*.

Species	F3 female <sup>1</sup>	F3 male <sup>2</sup>	Club female <sup>3</sup>	Club male <sup>4</sup>	Procoxa color <sup>5</sup>	Profemur color <sup>6</sup>	Mesofemur color <sup>7</sup>	Protibia color <sup>8</sup>	Mesotibia color <sup>9</sup>	Metatibia color <sup>10</sup>	Metasoma color <sup>11</sup>	Ovipositor to mesotibia <sup>12</sup>
<i>basilicus</i>	1	2	2	2	1	1	1	1	2	1	1	1
<i>campestris</i>	1	1	1	1	1	2	1	1	2	1	2	?
<i>coreae</i> sp. n.	1	1	2	2	1	4	1	3	5	3	2	2
<i>engaeus</i>	1	2	2	2	2	3	4	2	4	3	5	2
<i>fuscusae</i>	2	3	2	2	2	3	3	2	3	3	1	1
<i>glycinis</i> sp. n.	2	3	2	2	3	3	4	3	2	3	6	2
<i>gossypii</i>	1	1	1	1	1	2	1	1	1	1	2	2
<i>mali</i>	1	2	2	2	1	2	5	2	1	1	1	3
<i>paramali</i>	2	2	2	2	1	5	2	2	2	2	3	1
<i>rhamni</i> sp. n.	1	1	2	2	1	2	1	1	2	3	2	2
<i>sanborniae</i>	2	3	?	?	1	1	1	4	2	1	4	?
<i>spiracolae</i>	1	1	1	1	1	3	4	2	4	1	1	3

1- F3 female: 1 = subquadrate, 2 = at least 1.2× longer than wide

2- F3 male: 1 = subquadrate, 2 = 1.2 to 2.0× longer than wide, 3 = more than 2.0× longer than wide

3- Club female: 1 = less than 2.5× as long as wide, 2 = at least 2.5× as long as wide

4- Club male: 1 = less than 3× as long as wide, 2 = at least 3× as long as wide

5- Procoxae: 1 = dark, 2 = yellow, 3 = pale in females, dark grey in males

6- Profemora: 1 = dark, 2 = dark with apex pale, 3 = yellow or pale, 4 = yellow in females, middle part fuscous in males

7- Mesofemora: 1 = dark, 2 = dark with apex pale, 3 = yellowish white, 4 = yellow in females, middle part fuscous in males, 5 = middle part dark brown in both sexes

8- Protibia: 1 = pale brownish yellow with basal half dark brown, 2 = white, yellow or pale, 3 = pale to grey, 4 = pale yellow, often with middle part darker

9- Mesotibia: 1 = black with apex brownish yellow, 2 =- middle part dark, base and apex lighter, 3 = yellow or yellowish white, 4 = pale yellow, middle part dark, 5 = dark with distal half pale

10- Metatibia: 1 = dark brown or black, 2 = dark with apex pale, 3 = black or brown with base white, 4 = pale yellow, often with middle part darker

11- Metasoma: 1 = T1 or T1&T2 yellow, 2 = T1 or T1&T2 and apex pale, 3 = T1-T3 yellow, 4 = dark, black, 5 = female yellow with brown dorsum, except T1&T2, male dark with pale base, 6 = female yellow with brown dorsum except T1&T2, male base and apex pale

12- Ovipositor / mesotibia: 1 = less than 1.2, 2 = 1.3–1.5, 3 = more than 1.5



**Table 3.** List of anatomical terms and links to URI locations in the Hymenoptera Anatomy Ontology portal.

Term	Definition	URI
antenna	The anatomical cluster that is composed of the scape, pedicel and flagellum.	<a href="http://purl.obolibrary.org/obo/HAO_0000101">http://purl.obolibrary.org/obo/HAO_0000101</a>
apical denticle	The spur that is located distally on the gonossiculus.	<a href="http://purl.obolibrary.org/obo/HAO_0001574">http://purl.obolibrary.org/obo/HAO_0001574</a>
base	The tergum that is located on abdominal segment 2 AND The tergum that is located on the abdominal segment 3.	<a href="http://purl.obolibrary.org/obo/HAO_0000053">http://purl.obolibrary.org/obo/HAO_0000053</a> and <a href="http://purl.obolibrary.org/obo/HAO_0000056">http://purl.obolibrary.org/obo/HAO_0000056</a>
body	The anatomical cluster that is composed of the whole organism but which excludes the antennae, legs and wings.	<a href="http://purl.obolibrary.org/obo/HAO_0000182">http://purl.obolibrary.org/obo/HAO_0000182</a>
club	The anatomical cluster composed of the apical flagellomeres that are differentiated by size from the basal flagellomeres.	<a href="http://purl.obolibrary.org/obo/HAO_0001185">http://purl.obolibrary.org/obo/HAO_0001185</a>
compound eye	The compound organ that is composed of ommatidia.	<a href="http://purl.obolibrary.org/obo/HAO_0000217">http://purl.obolibrary.org/obo/HAO_0000217</a>
costal cell	The membranous region of the forewing anterior to the submarginal vein, measured from the basal constriction that delimits the apex of the humeral plate of the wing to the point at which the submarginal vein touches the leading edge of the wing.	<a href="http://purl.obolibrary.org/obo/HAO_0000226">http://purl.obolibrary.org/obo/HAO_0000226</a>
coxa	The leg segment that is connected to the body and to the trochanter via conjunctivae and muscles.	<a href="http://purl.obolibrary.org/obo/HAO_0000228">http://purl.obolibrary.org/obo/HAO_0000228</a>
digitus	The sclerite that is located distally on the parossiculus.	<a href="http://purl.obolibrary.org/obo/HAO_0000385">http://purl.obolibrary.org/obo/HAO_0000385</a>
edge	The margin that extends along the border of two areas that are oriented differently.	<a href="http://purl.obolibrary.org/obo/HAO_0000285">http://purl.obolibrary.org/obo/HAO_0000285</a>
eye margin	The margin of the compound eye.	<a href="http://purl.obolibrary.org/obo/HAO_0000672">http://purl.obolibrary.org/obo/HAO_0000672</a>
F1	The flagellomere that is proximally attached to the pedicel.	<a href="http://purl.obolibrary.org/obo/HAO_0001148">http://purl.obolibrary.org/obo/HAO_0001148</a>
F2	The flagellomere that is located distal to the first flagellomere.	<a href="http://purl.obolibrary.org/obo/HAO_0001883">http://purl.obolibrary.org/obo/HAO_0001883</a>
F3	The flagellomere that is located immediately distal to the second flagellomere.	<a href="http://purl.obolibrary.org/obo/HAO_0001895">http://purl.obolibrary.org/obo/HAO_0001895</a>
femur	The leg segment that is distal to the trochanter and proximal to the tibia.	<a href="http://purl.obolibrary.org/obo/HAO_0000327">http://purl.obolibrary.org/obo/HAO_0000327</a>
fore wing	The wing that is located on the mesothorax.	<a href="http://purl.obolibrary.org/obo/HAO_0000351">http://purl.obolibrary.org/obo/HAO_0000351</a>
frontoververtex	The anatomical cluster that is composed of the vertex and the dorsal area of the upper face dorsal to the frontofacial ridge.	<a href="http://purl.obolibrary.org/obo/HAO_0001823">http://purl.obolibrary.org/obo/HAO_0001823</a>
genitalia	The anatomical cluster that is composed of the cupula, gonostyle, volsella and the aedeagus.	<a href="http://purl.obolibrary.org/obo/HAO_0000312">http://purl.obolibrary.org/obo/HAO_0000312</a>
head	The tagma that is located anterior to the thorax.	<a href="http://purl.obolibrary.org/obo/HAO_0000397">http://purl.obolibrary.org/obo/HAO_0000397</a>
hind wing	The wing that is located on the metathorax.	<a href="http://purl.obolibrary.org/obo/HAO_0000400">http://purl.obolibrary.org/obo/HAO_0000400</a>
leg	The anatomical cluster that is composed of the coxa and all distal leg segments and is connected to the pectus.	<a href="http://purl.obolibrary.org/obo/HAO_0000494">http://purl.obolibrary.org/obo/HAO_0000494</a>



Term	Definition	URI
longitudinal sensillum	The multiporous plate sensillum that is elongate.	<a href="http://purl.obolibrary.org/obo/HAO_0001936">http://purl.obolibrary.org/obo/HAO_0001936</a>
mandible	The sclerite that is connected to the cranium along the anterior margin of the oral foramen via the anterior and posterior cranio-mandibular articulations.	<a href="http://purl.obolibrary.org/obo/HAO_0000506">http://purl.obolibrary.org/obo/HAO_0000506</a>
margin	The line that delimits the periphery of an area.	<a href="http://purl.obolibrary.org/obo/HAO_0000510">http://purl.obolibrary.org/obo/HAO_0000510</a>
marginal vein	The abscissa that is located along the anterior margin of the fore wing and is thought to correspond to the anterior abscissa of the radius (R1).	<a href="http://purl.obolibrary.org/obo/HAO_0000512">http://purl.obolibrary.org/obo/HAO_0000512</a>
mesobasitarsus	The basitarsus that is located in the mid leg.	<a href="http://purl.obolibrary.org/obo/HAO_0001133">http://purl.obolibrary.org/obo/HAO_0001133</a>
mesocoxa	The coxa that is located on the mid leg.	<a href="http://purl.obolibrary.org/obo/HAO_0000635">http://purl.obolibrary.org/obo/HAO_0000635</a>
mesofemur	The femur that is located on the mid leg.	<a href="http://purl.obolibrary.org/obo/HAO_0001131">http://purl.obolibrary.org/obo/HAO_0001131</a>
mesoscutum	The area that is located anterior to the transscutal articulation.	<a href="http://purl.obolibrary.org/obo/HAO_0001490">http://purl.obolibrary.org/obo/HAO_0001490</a>
mesosoma	The anatomical cluster that is composed of the prothorax, mesothorax and the metapodeal-propodeal complex.	<a href="http://purl.obolibrary.org/obo/HAO_0000576">http://purl.obolibrary.org/obo/HAO_0000576</a>
mesotibia	The tibia that is located on the mid leg.	<a href="http://purl.obolibrary.org/obo/HAO_0001351">http://purl.obolibrary.org/obo/HAO_0001351</a>
mesotibial spur	The tibial spur that is located on the mesotibia.	<a href="http://purl.obolibrary.org/obo/HAO_0001120">http://purl.obolibrary.org/obo/HAO_0001120</a>
metabasitarsus	The basitarsus that is located on the hind leg.	<a href="http://purl.obolibrary.org/obo/HAO_0001142">http://purl.obolibrary.org/obo/HAO_0001142</a>
metabasitarsus	The basitarsus that is located on the hind leg.	<a href="http://purl.obolibrary.org/obo/HAO_0001142">http://purl.obolibrary.org/obo/HAO_0001142</a>
metacoxa	The coxa that is located on the hind leg.	<a href="http://purl.obolibrary.org/obo/HAO_0000587">http://purl.obolibrary.org/obo/HAO_0000587</a>
metasoma	The tagma that is connected anteriorly to the metapodeal-propodeal complex at the propodeal foramen and consists of abdominal segments.	<a href="http://purl.obolibrary.org/obo/HAO_0000626">http://purl.obolibrary.org/obo/HAO_0000626</a>
metatibia	The tibia that is located on the hind leg.	<a href="http://purl.obolibrary.org/obo/HAO_0000631">http://purl.obolibrary.org/obo/HAO_0000631</a>
metatibial spur	The tibial spur that is located on the metatibia.	<a href="http://purl.obolibrary.org/obo/HAO_0001121">http://purl.obolibrary.org/obo/HAO_0001121</a>
mid lobe of mesoscutum	The area that is located between the notauli.	<a href="http://purl.obolibrary.org/obo/HAO_0000520">http://purl.obolibrary.org/obo/HAO_0000520</a>
occipital margin	The edge that separates the occiput from the vertex.	<a href="http://purl.obolibrary.org/obo/HAO_0001963">http://purl.obolibrary.org/obo/HAO_0001963</a>
ocellus	The multi-tissue structure that is located on the top of the head, composed of the corneal lens, pigment cell, rhabdoms and synaptic plexus.	<a href="http://purl.obolibrary.org/obo/HAO_0000661">http://purl.obolibrary.org/obo/HAO_0000661</a>
ovipositor	The anatomical cluster that is composed of the first valvulae, second valvulae, third valvulae, first valvifers and second valvifers .	<a href="http://purl.obolibrary.org/obo/HAO_0000679">http://purl.obolibrary.org/obo/HAO_0000679</a>
pedicel	The antennal segment that is the second segment of the antenna and is connected proximally with the scape and distally with the flagellum.	<a href="http://purl.obolibrary.org/obo/HAO_0000706">http://purl.obolibrary.org/obo/HAO_0000706</a>



Term	Definition	URI
phallobase	The anatomical cluster that is composed of the cupulae, gonostipites and volsellae.	<a href="http://purl.obolibrary.org/obo/HAO_0000713">http://purl.obolibrary.org/obo/HAO_0000713</a>
posterior ocellus	The ocellus that is paired.	<a href="http://purl.obolibrary.org/obo/HAO_0000481">http://purl.obolibrary.org/obo/HAO_0000481</a>
procoxa	The coxa that is located on the fore leg.	<a href="http://purl.obolibrary.org/obo/HAO_0001122">http://purl.obolibrary.org/obo/HAO_0001122</a>
profemur	The femur that is located on the fore leg.	<a href="http://purl.obolibrary.org/obo/HAO_0001124">http://purl.obolibrary.org/obo/HAO_0001124</a>
protibia	The tibia that is located on the fore leg.	<a href="http://purl.obolibrary.org/obo/HAO_0000350">http://purl.obolibrary.org/obo/HAO_0000350</a>
row	The anatomical cluster that is composed of repeated units of anatomical structures.	<a href="http://purl.obolibrary.org/obo/HAO_0000901">http://purl.obolibrary.org/obo/HAO_0000901</a>
scape	The antennal segment that is proximal to the pedicel and is connected with the head via the radicle.	<a href="http://purl.obolibrary.org/obo/HAO_0000908">http://purl.obolibrary.org/obo/HAO_0000908</a>
sculpture	The area that is located on the sclerite and that is composed of repetitive anatomical structures.	<a href="http://purl.obolibrary.org/obo/HAO_0000913">http://purl.obolibrary.org/obo/HAO_0000913</a>
scutellar sensillum	The campaniform sensillum that is paired and is located submedially on the mesoscutellum.	<a href="http://purl.obolibrary.org/obo/HAO_0001965">http://purl.obolibrary.org/obo/HAO_0001965</a>
scutellum	The area that is located posteriorly of the transscutal line and is composed of the axillae and the mesoscutellum.	<a href="http://purl.obolibrary.org/obo/HAO_0000572">http://purl.obolibrary.org/obo/HAO_0000572</a>
secretory pore	The anatomical space that corresponds to the distal end of an exocrine gland.	<a href="http://purl.obolibrary.org/obo/HAO_0001966">http://purl.obolibrary.org/obo/HAO_0001966</a>
seta	The sensillum that is multicellular and consists of trichogen, tormogen, and sense cells.	<a href="http://purl.obolibrary.org/obo/HAO_0000935">http://purl.obolibrary.org/obo/HAO_0000935</a>
side lobe	The area that is located between the notaulus and the parascutal carina.	<a href="http://purl.obolibrary.org/obo/HAO_0000466">http://purl.obolibrary.org/obo/HAO_0000466</a>
stigma	The patch on the wing that is sclerotized and is located on the anterior margin of the fore wing.	<a href="http://purl.obolibrary.org/obo/HAO_0000957">http://purl.obolibrary.org/obo/HAO_0000957</a>
submarginal vein	Basal-most portion of the forewing vein complex that occurs behind the costal cell; measured from the constriction that delimits the humeral plate to the point at which the vein touches the leading edge of the wing apically.	<a href="http://purl.obolibrary.org/obo/HAO_0000972">http://purl.obolibrary.org/obo/HAO_0000972</a>
T1	The tergum that is located on abdominal segment 2.	<a href="http://purl.obolibrary.org/obo/HAO_0000053">http://purl.obolibrary.org/obo/HAO_0000053</a>
T2	The tergum that is located on the abdominal segment 3.	<a href="http://purl.obolibrary.org/obo/HAO_0000056">http://purl.obolibrary.org/obo/HAO_0000056</a>
tarsus	The leg segment that is apical to the tibia.	<a href="http://purl.obolibrary.org/obo/HAO_0000992">http://purl.obolibrary.org/obo/HAO_0000992</a>
third valvula	The sclerite that is located posterior to the second valvifer and is connected to the second valvifer via conjuntiva.	<a href="http://purl.obolibrary.org/obo/HAO_0001012">http://purl.obolibrary.org/obo/HAO_0001012</a>
tooth	The projection that is located distally on the mandible.	<a href="http://purl.obolibrary.org/obo/HAO_0001019">http://purl.obolibrary.org/obo/HAO_0001019</a>
wing	The wing that is located on the mesothorax.	<a href="http://purl.obolibrary.org/obo/HAO_0000351">http://purl.obolibrary.org/obo/HAO_0000351</a>



## Results and discussion

Following the work of Zehavi and Rosen (1988), we consider the following traits to be diagnostic for the *A. mali* complex: (1) head and body dark except for parts of the metasoma; (2) metafemur pale, (3) a single complete row of setae proximal to the linea calva of the fore wing, with a few additional setae in the angle between this row and the marginal vein; (4) linea calva open (no setae at its posterior edge); (5) meso- and metacoxae dark; (6) metatibia more or less dark. The *A. mali* complex consists of eleven described species, and there are six similar species with either a dark metafemur or more than one line of setae proximal to the linea calva (Table 1). Species within the complex have been distinguished by color and shape of antennal segments (particularly the third funicular segment), color of legs and metasoma, and relative length of ovipositor versus mesotibia (Ashmead 1888; Evans et al. 1995; Gahan 1924; Girault 1913; Haldeman 1851; Hayat 1998; Prinsloo and Neser 1994; Timberlake 1924; Yas-nosh 1963; Zehavi and Rosen 1988).

### Key to species in the *Aphelinus mali* complex

- 1 Female: procoxa white or yellowish-white, male: procoxa yellowish-white or grey, both sexes: meso- and metacoxae dark ..... **2**
- All coxae dark in both sexes ..... **4**
- 2(1) F3 more than twice as long as broad in male, subquadrate in female.... ***engaeus***
- F3 less than twice as long as broad in male and from subquadrate to more than 1.4× as long as broad in female. .... **3**
- 3(2) Procoxa yellowish white in male; metatibia yellowish white; metabasitarsus pale; club light brown in male; metasoma dark with base yellow in female and slightly pale in male; ovipositor less than 1.2× middle tibia ..... ***fuscusae***
- Procoxa grey in male, particularly on anterior surface; metatibia dark in center; metabasitarsus greyish brown; club yellow in male; metasoma dark with T1&2, venter, and apex yellow in female and base and apex yellow in male; ovipositor more than 1.2× mesotibia..... ***glycinis* sp. n.**
- 4(1) F3 longer than broad in male and subquadrate to longer than broad in female; metasoma dark or dark with pale base, but with apex dark ..... **5**
- F3 subquadrate in both male and female; metasoma dark with pale base or pale base and apex..... **8**
- 5(4) Pro- and metafemur dark; protibia dark or dark with yellow apex; metasoma dark or dark with pale base ..... **6**
- Pro- and metafemur partly yellow; protibia yellow; metasoma dark with pale base..... **7**
- 6(5) Scape yellow to pale brown with apical third yellow; pedicel and club infus-cate brown; metabasitarsus dark; F3 subquadrate in female and 1.2–2× as long as broad in male; metasoma dark with pale base ..... ***basilicus***



- Scape dark brown to black; pedicel yellow in female and yellow to dusky in male; club yellow; metabasitarsus yellow; F3 longer than broad in female and more than 2× as long as broad in male; metasoma dark. .... *sanborniae*
- 7(6) Pro- and mesofemur dark with base and apex pale; protibia dark with pale base and apex, metatibia dark with pale apex; F3 1.2–1.5 as long as broad in female and 1.2–2× as long as broad in males; ovipositor equal to metatibia; metasoma dark with T1–T3 yellow ..... *paramali*
- Pro- and mesofemur dark with apex pale; protibia dark with brownish yellow apex, metatibia dark; F3 subquadrate in female and 1.2–2× as long as broad in male; ovipositor more than 1.5× mesotibia; metasoma dark with T1 or T1&2 yellow. .... *mali*
- 8(4) Profemur pale yellow, mesofemur pale yellow in female, dark brown in male; metabasitarsus yellow; metasoma dark with base yellow ..... *spiraecolae*
- Profemur dark with apex pale yellow, mesofemur dark in both sexes; metabasitarsus dark; metasoma dark with base and apex yellow. .... 9
- 9(8) Club more than 2× as long as broad in female; metatibia dark with pale base... 11
- Club 2× as long as broad in females; metatibia all dark. .... 10
- 10(9) Club and pedicel light brown in female and darker in males; mesofemur dark; mesotibia dark with pale base and apex ..... *campestris*
- Club pale yellow in female and male; pedicel dusky yellow in female and light brown in male; mesotibia dark with brownish yellow apex ..... *gossypii*
- 11(9) Club more than 3× as long as broad in males; scape yellowish white in female and infusate brown in male; mesotibia dark with base and apex pale .....  
..... *rhamni* sp. n.
- Club less than 3× as long as broad in males; scape dark brown with distal half yellow in both sexes; mesotibia dark with distal half yellow ..... *coreae* sp. n.

## Taxonomy

### *Aphelinus glycinis* Hopper & Woolley, sp. n.

[urn:lsid:zoobank.org:act:1132B1E4-8F2E-4FF3-9E6B-30FAFD497EA1](http://zoobank.org/act:1132B1E4-8F2E-4FF3-9E6B-30FAFD497EA1)

[http://species-id.net/wiki/Aphelinus\\_glycinis](http://species-id.net/wiki/Aphelinus_glycinis)

Figs 1–14

**Diagnosis. Female.** Head and mesosoma dark brown to black; legs with procoxa yellowish white, meso- and metacoxae dark brown to black, femora yellowish white, protibia yellowish white, mesotibia yellowish white with center greyish, metatibia dark grey to black with base pale; metasoma with base, apex, and venter yellow, remainder brown; antenna white to yellowish white; F3 1.3–1.7 times as long as broad; club 3.2 times as long as broad. **Male** similar except procoxa grey; pro- and mesofemur sometimes with darkened center; metasoma brown with base and apex yellow; scape dark greyish brown with greyish yellow distal tip, swollen in center, maximum width 3× distal end width, with three to five





**Figures 1–6.** *Aphelinus glycinis* sp. n. paratype specimens in 95% ethanol. **1** male antennae and face **2** female antennae and face **3** male, lateral view **4** female, lateral view **5** male, ventral view **6** female, ventral view.

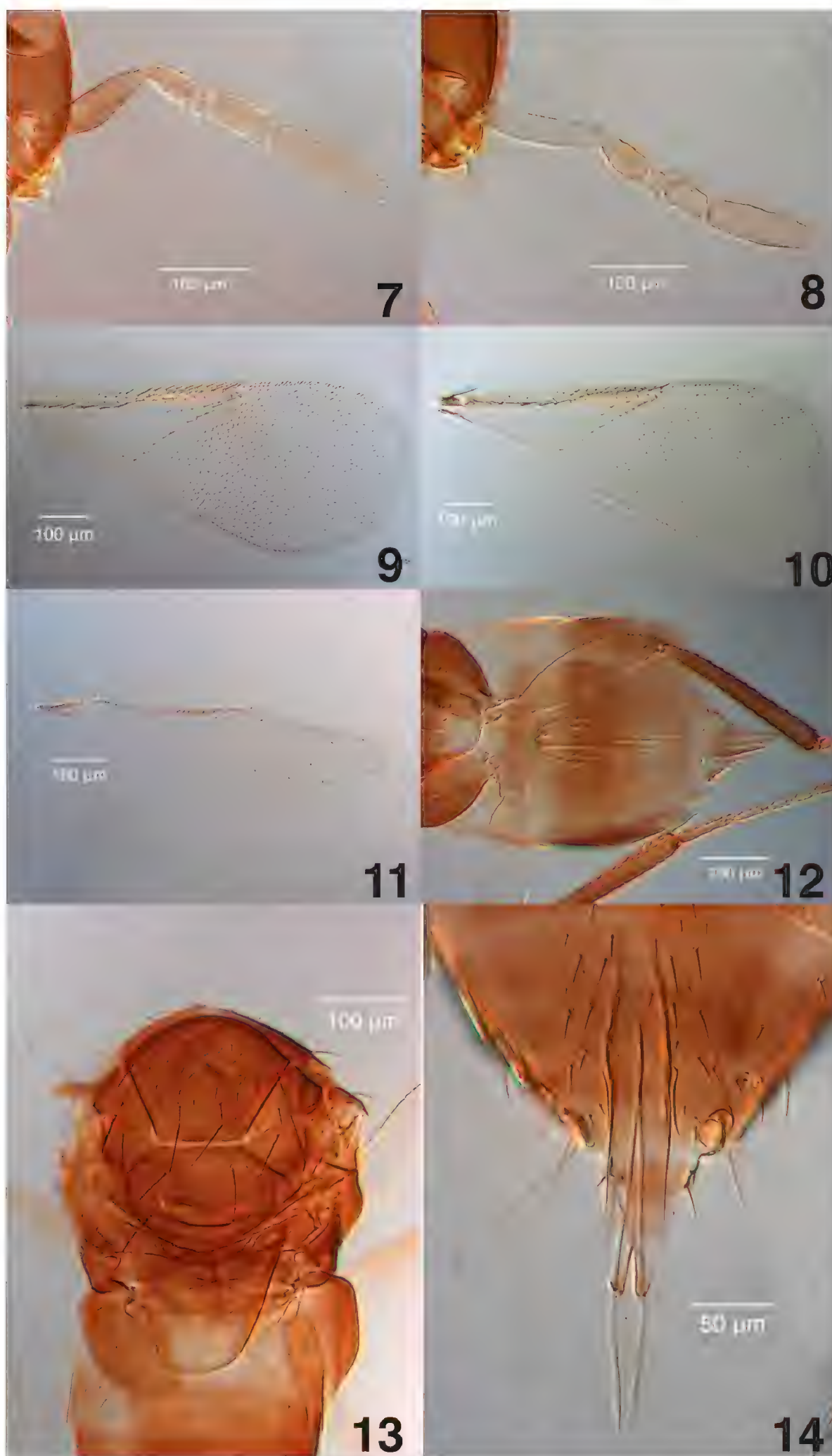
volcano-shaped secretory pores in a single line on ventral surface, pedicel greyish yellow, third funicle more than 2 times as long as broad, club 3.9 times as long as broad.

**Description.** Female (Figs 2, 4, 6, 8, 10, 11, 12, 13).

*Body length.* 0.77–0.93 (Holotype 0.90 mm).

*Head.* (Figs 2, 8) Head 1.3× as broad as high in frontal view, about as broad as mesosoma; frontovertex width 0.4× of head width, 1.2× as long as broad, and 0.8× as broad as scape length; posterior ocelli 1.0× their diameter from eye margin, 3× their diameter from one another, and 0.33× their diameter from occipital margin; mandible with 2 acute teeth and a broad truncate surface below the teeth, antenna as in Fig. 8 with scape 4.8× as long as broad, pedicel 2.2× as long as broad, F1 anneliform, 1.7× as





**Figures 7–14.** *Aphelinus glycinis* sp. n., slide-mounted paratypes. **7** male antenna (TAMU x0616203) **8** female antenna (TAMU x0616201) **9** male fore wing (TAMU x0616206) **10** female fore wing (TAMU x0616201) **11** female hind wing (TAMU x0616204) **12** female metasoma (TAMU x0616204) **13** female mesosoma (TAMU x0616211) **14** male genitalia (TAMU x0616206).



wide as long, F2 1.2× as broad as long, F3 1.6–1.7× as long as broad, club 3.2× as long as broad, 2.7× times as long as F3, and with 6–7 longitudinal sensilla.

*Mesosoma*. (Figs 4, 6, 13) Mesoscutum and scutellum with fine reticulate sculpture, longest diameter of reticulations approximately twice the diameter of the scutellar sensilla, interior of reticulations with fine, granulate surface (visible only in slide-mounts under high magnification); mid-lobe of mesoscutum with 2 pairs of long setae and about 40 short setae, side lobes each with 2 long and 1 short setae; scutellum with 2 pairs of long setae and two sensilla directly posterior to the anterior pair of setae, scutellar sensilla slightly posterior to middle of scutellum; mesotibial spur 0.8× mesobasitarsus; metatibial spur 0.6× metabasitarsus.

*Fore wing*. (Fig. 10) 2.3× as long as broad; costal cell with 1 complete row of dorsal setae and 2 rows of ventral setae, the posterior row extending from under the proximal end of the marginal vein almost to stigma, costal cell 1.2× longer than marginal vein; submarginal vein with 5–6 setae; marginal vein with 10 setae along the margin; stigmal vein short with stigma rounded; delta region proximal to linea calva with one complete line of 13–15 setae and 2–6 additional setae in angle with marginal vein, linea calva with no dorsal setae at its posterior edge; wing distal to linea calva with dense, evenly spaced, dorsal setae and much smaller ventral setae.

*Hind wing*. (Fig. 11) 4.3× as long as broad, marginal fringe 0.26× wing width.

*Metasoma*. (Figs 4, 6, 12) 1.2× as long as mesosoma; ovipositor inserted at middle of metasoma, slightly exerted distally, 1.3× as long as meso- and metatibiae; third valvula one-third length of ovipositor.

*Color*. (Figs 2, 4, 6) Head and mesosoma dark brown to black; legs with procoxa yellowish white, meso- and metacoxae dark brown to black, femora yellowish white, protibia yellowish white, mesotibia yellowish white with center greyish, metatibia dark grey to black base pale, tarsi pale brown with tips and metabasitarsus greyish brown; metasoma with base (T1 and T2), apex, and venter yellow, remainder brown; antennae yellowish white; compound eyes burgundy, and ocelli red in life, both silver-colored in dried specimens.

**Male** (Figs 1, 3, 5, 7, 9, 14). Similar to female except:

*Head*. (Figs 1, 7) Antenna with scape swollen in middle, 3.4 as long as broad, maximum width 3× distal end width, with 3–5 volcano-shaped secretory pores in line on ventral surface, pedicel 2.1× as long as broad, F1 anneliform, 1.8× as wide as long, F2 1.5× as broad as long, F3 2.0× as long as broad, club 3.9× as long as broad, 2.1× as long as F3, and with 4–6 longitudinal sensilla.

*Metasoma*. (Figs 3, 5, 14) About the same length as mesosoma, phallobase of genitalia including digiti 4.5× longer than broad, digiti about twice longer than broad and with two apical denticles.

*Color*. (Figs 1, 3, 5) Legs with procoxa grey, pro- and mesofemora sometimes with darkened centers; metasoma brown with base and apex yellow; scape dark greyish brown with greyish yellow distal tip, pedicel greyish yellow.

**Holotype female** (card-mounted, deposited in USNM, USNM ENT 00703637). “China: Liaoning, Xiuyan | 40°18'N, 123°14'E | 11.vii.2007, K. Hoelmer || ex: *Aphis*



*glycines* | on: soybean | plots 1/3, 2007/007 || From Lab Culture | USDA-ARS-BIIRU | Newark, Delaware”

**Paratypes** (USNM, TAMU, BMNH). 30 card-mounted and 4 slide-mounted ♀♀, 14 card-mounted and 4 slide-mounted ♂♂ with same data as holotype. 13 card-mounted and 4 slide-mounted ♀♀ and 9 card-mounted and 3 slide-mounted females: **China**, Liaoning, Xiuyan, 40°20'N 116°6'E, 12.vii.2007, K. Hoelmer, ex: *Aphis glycines* on: soybean, plot 2, 2008/008, from Lab Culture, USDA-ARS-BIIRU, Newark, Delaware, all bearing TAMU accession numbers.

**Hosts.** In the field, *Aphis glycines* is the only known host. In laboratory experiments, *A. glycinis* parasitizes *A. glycines* and closely related species in the genus *Aphis*.

**Etymology.** This species is named for the host from which it was collected. The species epithet is a noun in genitive case.

**Relationships.** *Aphelinus glycinis* is closest to *A. engaeus* and *A. ficusae* Prinsloo and Naser based on our matrix of traits (Table 2). *Aphelinus glycinis* differs from *A. engaeus* in having elongated third funicle segments in males and females, and it differs from *A. ficusae* in having an ovipositor more than 1.2× as long as the mesotibia and grey procoxa in males. It also differs from these species in its aphid hosts and geographical distribution. *Aphelinus glycinis* is a specialist on *Aphis* species close to *Aphis glycines*, but *A. engaeus* is reported from *Schizaphis graminum* (Rondani) and *Sitobion ochnearum* (Eastop) and *A. ficusae* was reared from an undetermined aphid on *Ficus sycomorus* (Prinsloo and Naser 1994). Furthermore, *Aphelinus glycinis* was collected in northeastern China, whereas *A. engaeus* and *A. ficusae* have been reported only from South Africa.

### *Aphelinus rhamni* Hopper & Woolley, sp. n.

[urn:lsid:zoobank.org:act:1132B1E4-8F2E-4FF3-9E6B-30FAFD497EA1](http://zoobank.org/urn:lsid:zoobank.org:act:1132B1E4-8F2E-4FF3-9E6B-30FAFD497EA1)

[http://species-id.net/Aphelinus\\_rhamni](http://species-id.net/Aphelinus_rhamni)

Figs 15–28

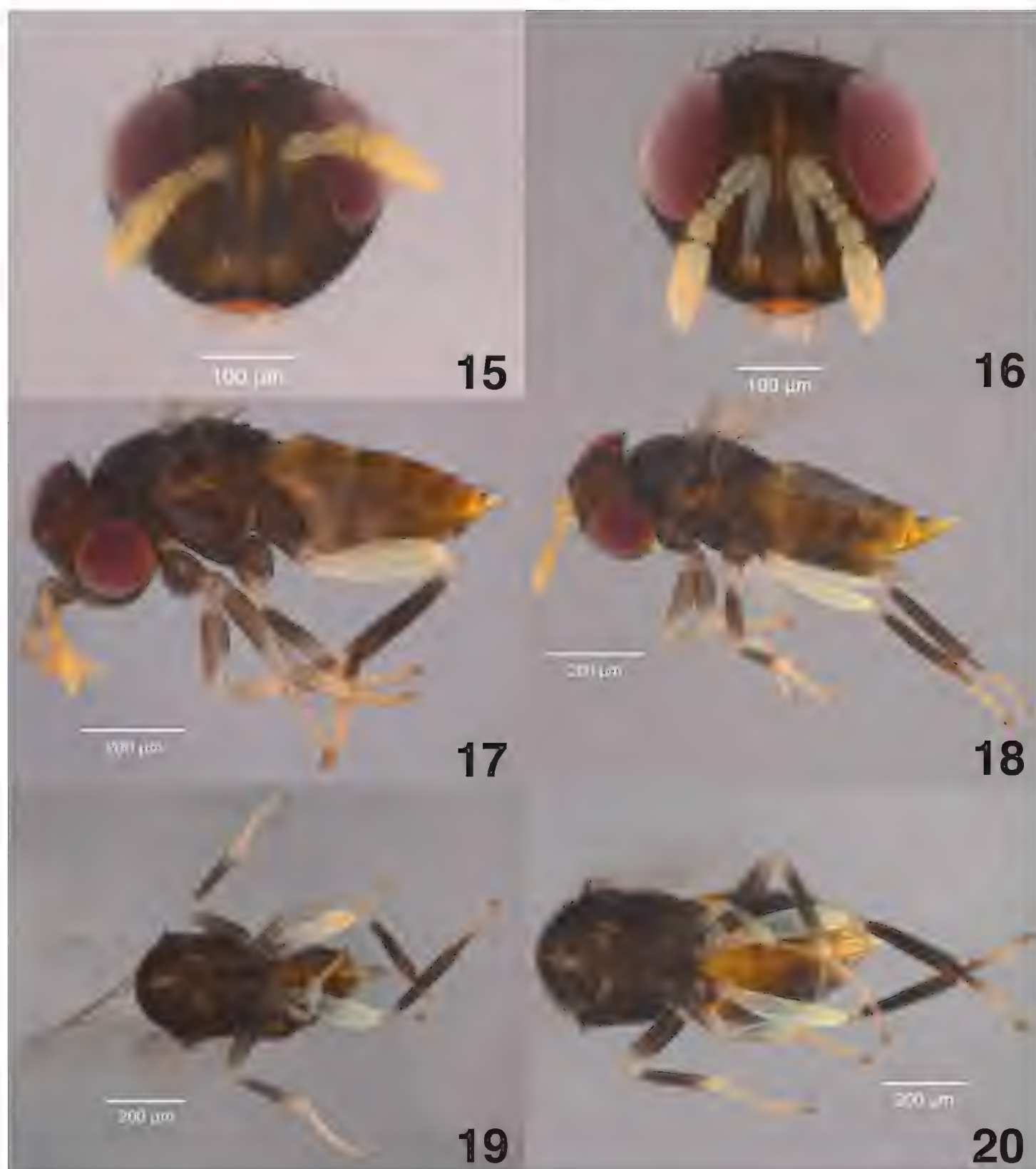
**Diagnosis. Females.** Head and mesosoma dark brown to black; legs with coxae dark brown to black, profemur dark grey with pale apex, mesofemur dark grey to black, metafemur white, protibia white with pale greyish base, mesotibia dark grey to black with pale base and apex, and metatibia dark grey to black with pale base; metasoma yellowish brown with base and apex yellow; antennae yellow with basal half of scape and pedicel sometimes greyish; F3 quadrate; club 2.8 times as long as broad. **Males** similar except scape swollen in middle, 3× broader in middle than at distal end, with 2 or 3 volcano-shaped secretory pores; scape dark yellowish grey, pedicel pale greyish yellow; club 3.3 times as long as broad.

**Description.** Female (Figs 16, 18, 20, 22, 24, 25, 26, 27).

*Body length.* 0.75–0.94 (Holotype 0.87 mm).

*Head.* (Figs 16, 22) Head 1.2× as broad as high in frontal view, about as broad as mesosoma; frontovertex 0.4× head width and as broad as scape length; posterior ocelli





**Figures 15–20.** *Aphelinus rhamni* sp. n., paratype specimens in 95% ethanol. **15** male antennae and face **16** female antennae and face **17** male, lateral view **18** female, lateral view **19** male, ventral view **20** female, ventral view.

0.5× their diameter from eye margin, 3.0× their diameter from one another, and 0.33× their diameter from occipital margin; mandible with 2 acute teeth and a broad truncate surface below the teeth; antennae as in Fig. 21 with scape 4.8 longer than broad, pedicel 1.8× as long as broad, F1 anneliform, F2 1.5× as broad as long, F3 quadrate, club 2.8× as long as broad and 3.3× times longer than F3, with 4–6 longitudinal sensilla.

*Mesosoma.* (Figs 18, 20, 27) Mesoscutum and scutellum with fine reticulate sculpture, longest diameter of reticulations approximately twice the diameter of scutellar





**Figures 21–28.** *Aphelinus rhamni* sp. n., slide-mounted paratypes. **21** male antenna (TAMU x0616221) **22** female antenna (TAMU x0616215) **23** male fore wing (TAMU x0616217) **24** female fore wing (TAMU x0616215) **25** female hind wing (TAMU x0616129) **26** female metasoma (TAMU x0616214) **27** female mesosoma (TAMU x0616129) **28** male genitalia (TAMU x0616217).



sensilla, interior of reticulations with fine, granulate surface (visible only in slide-mounts under high magnification); mid-lobe of mesoscutum with 2 pairs of long setae and 35–40 short setae, side lobes each with 2 long and 1 short seta; scutellum with 2 pairs of long setae, pair of scutellar sensilla directly posterior to the anterior pair of setae and slightly posterior to middle of scutellum; mesotibial spur equal in length to mesobasitarsus; metatibial spur 0.5× metabasitarsus.

*Fore wing.* (Fig. 24) 2.2× as long as broad; costal cell with 1 row of dorsal setae and two rows of ventral setae, the posterior row extending from under the proximal end of the marginal vein almost to stigma, costal cell 1.1× as long as marginal vein; submarginal vein with 5 setae, marginal vein with 10 setae along the anterior margin; stigmal vein short with stigma rounded; delta region proximal to linea calva with one complete line of 13–15 setae and 2–6 additional setae in angle with marginal vein, linea calva with no setae at its posterior edge; wing distal to linea calva with evenly spaced, dense dorsal setae and much smaller ventral setae.

*Hind wing.* (Fig. 25) 3.9× longer than broad, marginal fringe 0.23× wing width.

*Metasoma.* (Figs 18, 20, 26) 1.4× as long as mesosoma; ovipositor inserted at middle of metasoma, slightly exerted distally, 1.3× longer than metatibia and mesotibia; third valvulae one-third the length of ovipositor.

*Color.* (Figs 16, 18, 20) Head and mesosoma dark brown to black; legs with coxae dark brown to black, profemur dark grey with pale apex, mesofemur dark grey to black, metafemur white, protibia white with pale greyish base, mesotibia dark grey to black with pale base and apex, and metatibia dark grey to black with pale base; metasoma yellowish brown with venter of T1 and apex yellow; antennae yellow sometimes with basal half of scape and pedicel greyish yellow; compound eyes dark burgundy and ocelli red in life, both silver-colored in dried specimens.

**Male** (Figs 15, 17, 19, 21, 23, 28). Similar to female except:

*Body length.* 0.66–0.78 mm.

*Head.* (Figs 15, 21) Antenna with scape swollen in center, 3.1× as long as broad, maximum width 3× width at distal end, with 2–3 volcano-shaped secretory pores in single line on ventral surface, pedicel 1.8× as long as broad, F1 subquadrate, 1.1× as broad as long, F2 shorter, 1.4× as broad as long, F3 trapezoidal, 1.1× longer than width at apex, 1.5× as long as wide at base, club 3.3× as long as broad, with 4 longitudinal sensilla.

*Metasoma.* 0.7× length of mesoma

*Color.* (Figs 15, 17, 19) Scape dark yellowish grey, pedicel pale greyish yellow, base of metasoma pale brown and with yellow region at apex smaller.

**Holotype female** (card-mounted, deposited in USNM, USNM ENT 00763638). “China, Daxing (Beijing) | 39°48'N, 116°28'E | 10.ix.2005, K. Hoelmer || ex: *Aphis glycines* | on: *Rhamnus* sp. | 2005/005 || From Lab Culture | USDA-ARS-BIIRU | Newark, Delaware”

**Paratypes** (USNM, TAMU, BMNH). 33 card-mounted and 6 slide-mounted females, 19 card-mounted and 3 slide-mounted males with same data as holotype. 9 card-mounted and 2 slide-mounted females, 6 card-mounted and 2 slide-mounted males: **China:** Daxing (Beijing), 39°48'N 116°28'E, 10.iv.2004, W. Meikle coll.,



ex: *Aphis glycines* on *Rhamnus* sp., 2004/008, from lab culture, USDA-ARS-BIIRU, Newark, Delaware.

**Host.** In the field, *Aphis glycines* is the only known host. In laboratory experiments, *A. rhamni* parasitizes *A. glycines* and closely related species in the genus *Aphis*, and rarely *Rhopalosiphum padi* L. and *Schizaphis graminum*.

**Etymology.** This species is named for the primary host plant of the aphid species from which it was collected. The species epithet is a noun in genitive case.

**Relationships.** *Aphelinus campestris* and *Aphelinus gossypii* are the closest described species to *A. rhamni* based on our matrix of traits (Table 2). *Aphelinus rhamni* differs from both species in having a more elongate club and in coloration of the metatibia. *Aphelinus rhamni* has a much narrower host range than *A. gossypii*, which is reported from at least 18 species of aphids in 10 genera and two tribes, including species which *A. rhamni* does not parasitize in laboratory experiments.

### *Aphelinus coreae* sp. n.

[urn:lsid:zoobank.org:act:F4B3A880-2136-474C-815C-13406F2A48A0](http://urn:lsid:zoobank.org:act:F4B3A880-2136-474C-815C-13406F2A48A0)

[http://species-id.net/Aphelinus\\_coreae](http://species-id.net/Aphelinus_coreae)

Figs 29–42

**Diagnosis. Females.** Head and thorax dark brown to black; legs with coxae dark brown to black, profemur dark grey with distal half pale, mesofemur dark grey to black, metafemur pale yellowish white, protibia pale yellowish white to somewhat fuscous, mesotibia dark grey to black with distal half pale, and metatibia dark grey to black with pale base; metasoma dark brown with base and apex yellow; antennae yellow; F3 quadrate. **Males** similar except scape swollen in middle, 2.0× as broad in middle than at distal end, with two or occasionally three circular secretory pores in the middle of a shallow depression on ventral surface, scape dark yellowish grey with distal half yellow, pedicel greyish yellow.

**Description.** Female (Figs 30, 32, 34, 36, 38, 39, 40, 41).

*Body length.* 0.80–0.93 (Holotype 0.93 mm).

*Head.* (Figs 30, 36) Head 1.3× as broad as high in frontal view, about as broad as mesosoma; frontovertex 0.4× head width and as broad as scape length; posterior ocelli approximately their own diameter from eye margin, 5× their diameter from one another, and 0.5× their diameter from occipital margin; mandible with two acute teeth and a broad truncate surface below the teeth, ventral tooth sometimes not distinct; antennae as in Figs 30 and 36 with scape 4.0× as long as broad, pedicel 1.6× as long as broad, F1 anneliform, F2 1.4× as broad as long, F3 subquadrate or very slightly broader than long, club 3.75× as long as broad and 3.5× longer than F3, with 7–8 linear sensilla.

*Mesosoma.* (Figs 32, 34, 41) Mesosoma and scutellum with fine reticulate sculpture, longest diameter of reticulations approximately 2–3× diameter of scutellar sensilla; interior of reticulations with fine, granulate surface (visible only in slide-mounts under high magnification), mid-lobe of mesoscutum with 2 pairs of long setae and about 40–60

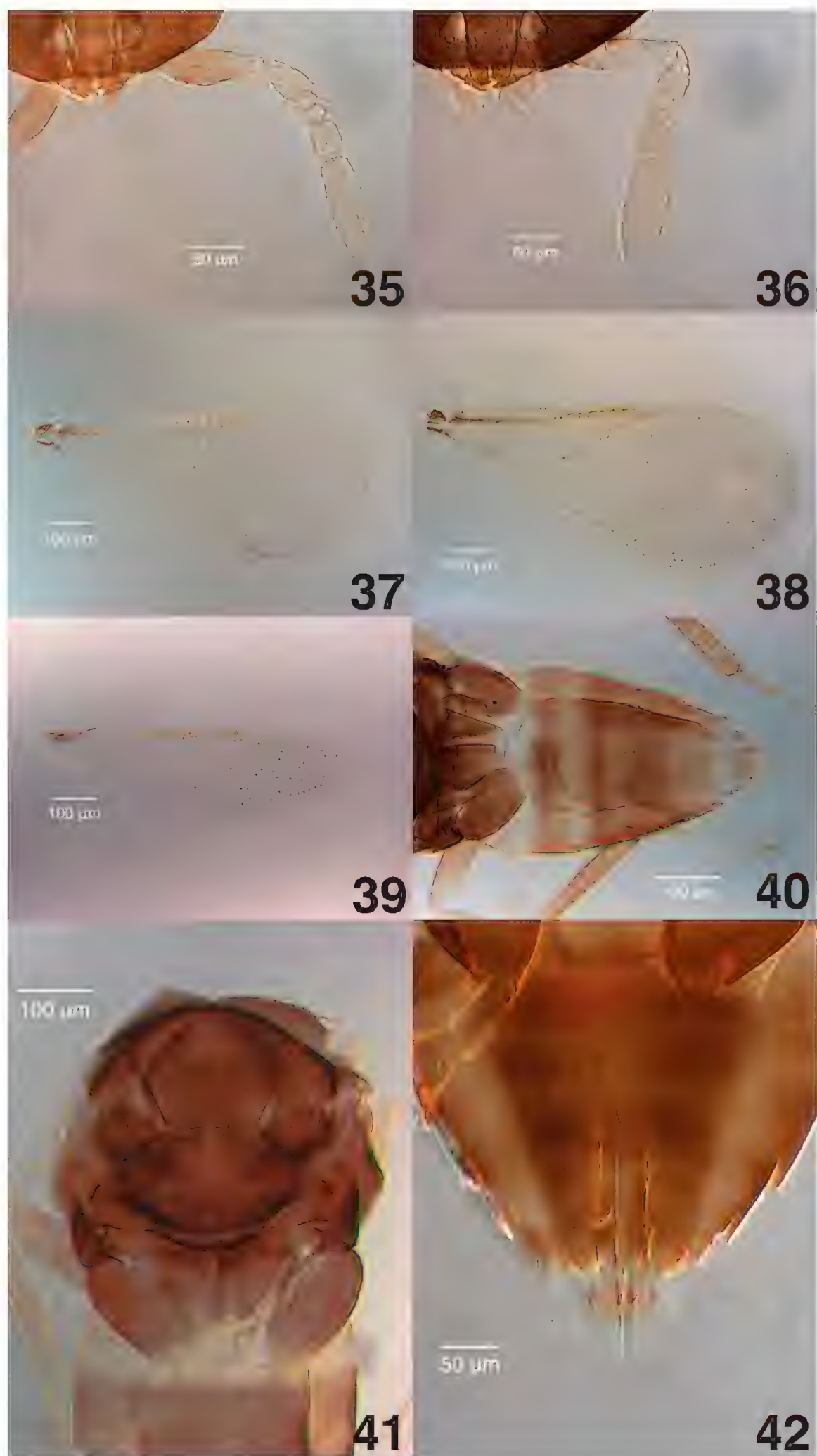




**Figures 29–34.** *Aphelinus coreae* sp. n., paratype specimens in 95% ethanol. **29** male antennae and face **30** female antennae and face **31** male, lateral view **32** female, lateral view **33** male, ventral view **34** female, ventral view.

short setae, side lobes each with 2 long and 1–2 short setae; scutellum with 2 pairs of long setae; pair of scutellar sensilla approximately equidistant from anterior and posterior pairs of long setae; mesotibial spur  $1.1\times$  mesobasitarsus; metatibial spur  $0.6\times$  metabasitarsus.





**Figures 35–42.** *Aphelinus coreae* sp. n., slide-mounted paratypes. **35** male antenna (TAMU x0616221) **36** female antenna (TAMU x0616215) **37** male fore wing (TAMU x0616217) **38** female fore wing (TAMU x0616215) **39** female hind wing (TAMU x0616129) **40** female metasoma (TAMU x0616214) **41** female mesosoma (TAMU x0616129) **42** male genitalia (TAMU x0616217).



**Fore wing.** (Fig. 38) 2.2× as long as broad; costal cell with 1 row of dorsal setae and 2 rows of ventral setae, the posterior row extending from under the distal end of the submarginal vein almost to stigma, costal cell 1.3× as long as marginal vein; submarginal vein with 5 setae; marginal vein with 12 setae along the anterior margin; stigmal vein short with stigma rounded; delta region proximal to linea calva with one complete line of 12–13 setae and 2–5 additional setae in angle with marginal vein, linea calva with no setae at its posterior edge; wing distal to linea calva with evenly spaced, dense dorsal setae and much smaller ventral setae.

**Hind wing.** (Fig. 39) 3.9× as long as broad, marginal fringe 0.26× wing width.

**Metasoma.** (Figs 32, 34, 40) 1.1× as long as mesosoma; ovipositor inserted at basal third of metasoma, slightly exerted distally, 1.4× as long as metatibia or mesotibia; third valvula 0.28× length of ovipositor.

**Color.** (Figs 30, 32, 34) Head and mesosoma dark brown to black; legs with coxae dark brown to black, profemur dark grey with distal half pale, mesofemur dark grey to black, metafemur pale yellowish white, protibia pale yellowish white to somewhat fuscous, mesotibia dark grey to black with distal half pale, and metatibia dark grey to black with pale base; metasoma dark brown with base and apex yellow; antennae yellow; compound eyes dark burgundy, ocelli red in life, both silver-colored in dried specimens.

**Male** (Figs 29, 31, 33, 35, 37, 42). Similar to female except:

**Body length.** 0.68–0.81 mm.

**Head.** (Figs 29, 35) Antenna with scape swollen in center, 3.3× as long as broad, maximum width 2× distal width, with 2 or 3 circular, secretory pores in the middle of a shallow depression on ventral surface, pedicel 2.0× longer than broad, F1 and F2 1.4× broader than long, F3 rectangular, 1.3× as long as wide at apex, club 3.2× as long as broad, with 3–4 longitudinal sensilla.

**Metasoma.** (Figs 31, 33, 42) 1.5× length of mesoma.

**Color.** (Figs 29, 31, 33) Scape dark yellowish grey with distal half yellow, pedicel greyish yellow.

**Holotype female** (card-mounted, deposited in USNM, USNM ENTO 00763639). “Korea, Gyeongsangnam Province, Miryang [35°30'N, 128°44'E | 11.viii.2009, K. Hoelmer || ex: *Aphis glycines* | on: soybean | 2009/011 || From Lab Culture | USDA-ARS-BIIRU | Newark, Delaware”

**Paratypes** (USNM, TAMU, BMNH). 13 card-mounted and 3 slide-mounted ♀♀ and 9 card-mounted and 5 slide-mounted ♂♂ with same data as holotype.

**Other material examined.** None.

**Host.** In the field, *Aphis glycines* is the only known host. In laboratory experiments, *A. coreae* parasitizes *A. glycines* and other species in the genus *Aphis*, and occasionally *Rhopalosiphum padi* and *Schizaphis graminum*.

**Etymology.** This species is named for its country of origin. The species epithet is a noun in genitive case.

**Relationships.** *Aphelinus campestris* and *Aphelinus gossypii* are the closest described species *A. coreae* based on our matrix of traits (Table 2). *Aphelinus coreae* differs from both species in having a more elongate club in females and in coloration of the scape



and mesotibia. Like *A. rhamni*, *A. coreae* has a much narrower host range than *A. gossypii*. *Aphelinus coreae* is very close to *A. rhamni*, but male *A. coreae* have shorter clubs and, as noted in the key, the two species differ in coloration of scape and mesotibia. Although difficult to distinguish, these species are reproductively isolated in laboratory crosses. Their DNA differs by 2130 fixed substitutions and 293 indels across 1.8 megabases of homologous DNA sequence. They also differ in host specificity: *A. coreae* parasitizes species of *Aphis*, e.g. *A. nerii* Boyer de Fonscolombe and *A. rumicis* L., not parasitized by *A. rhamni* in laboratory experiments.

## Acknowledgements

Alyssa Mann, undergraduate student at Texas A&M University, helped with digital imaging and preparation of figures. Kathryn Lanier, USDA-ARS, Newark, Delaware, reared the cultures of *A. coreae*, *A. glycinis* and *A. rhamni*. We thank István Miko for his generous help in reading the ms and helping us to standardize our terminology according to the Hymenoptera Anatomy Ontology project, and for providing the table of uri's for anatomical terms used in the paper. We thank the editors and two anonymous reviewers for their suggestions. This research was supported in part by funding from the North Central Soybean Research Program (KRH) and NSF award DEB 0730616 (JBW).

## References

- Ashmead WH (1888) Descriptions of some new North American Chalcididae. III: Euderinae (Hymenoptera: Chalcidoidea). Canadian Entomologist 20: 101–107. doi: 10.4039/Ent20101-6
- Campbell BC, Steffen-Campbell JD, Werren JH (1993) Phylogeny of the *Nasonia* species complex (Hymenoptera: Pteromalidae) inferred from an internal transcribed spacer (ITS2) and 28S rDNA sequences. Insect Molecular Biology 2: 225–237. doi: 10.1111/j.1365-2583.1994.tb00142.x
- Carver M (1980) A new species of *Aphelinus* Dalman (Hymenoptera: Chalcidoidea: Encyrtidae). Proceedings of the Entomological Society of Washington 82: 536–540.
- Clarke AR, Walter GH (1995) “Strains” and the classical biological control of insect pests. Canadian Journal of Zoology-Revue Canadienne De Zoologie 73: 1777–1790. doi: 10.1139/z95-210
- Darling DC, Werren JH (1990) Biosystematics of *Nasonia* (Hymenoptera: Pteromalidae): Two new species reared from birds' nests in North America. Annals of the Entomological Society of America 83: 352–370.
- DeBach P (1969) Uniparental, sibling and semi-species in relation to taxonomy and biological control. Israel Journal of Entomology 4: 11–28.
- Evans GA, Schauff ME, Kokyokomi ML, Yokomi RK (1995) A new species of *Aphelinus* (Hymenoptera, Aphelinidae) that parasitizes the Spirea aphid, *Aphis spiraecola* Patch (Homoptera, Aphididae). Proceedings of the Entomological Society of Washington 97: 17–21.



- Gahan AB (1924) Some new parasitic Hymenoptera with notes on several described forms. *Proceedings of the United States National Museum* 65: 9
- Gibson GAP (1997) Morphology and Terminology. Chapter 2, In: Gibson GAP, Huber JH, Woolley JB (Eds) *Annotated Keys to the Genera of Nearctic Chalcidoidea (Hymenoptera)*. NRC Research Press, Ottawa, 16–44.
- Girault AA (1913) Australian Hymenoptera Chalcidoidea - IV. *Memoirs of the Queensland Museum* 2: 181–295.
- Haldeman SS (1851) *Eriophilus mali*. *Pennsylvania Farm Journal* 1: 130–131.
- Hayat M (1998) Aphelinidae of India (Hymenoptera: Chalcidoidea): a taxonomic revision. *Memoirs on Entomology, International* 13: 81–83.
- Heraty JM, Woolley JB, Hopper KR, Hawks DL, Kim JW, Buffington M (2007) Molecular phylogenetics and reproductive incompatibility in a complex of cryptic species of aphid parasitoids. *Molecular Phylogenetics and Evolution* 45: 480–493. doi 10.1016/j.ympev.2007.06.021
- Hopper KR, Roush RT, Powell W (1993) Management of genetics of biological-control introductions. *Annual Review of Entomology* 38: 27–51. doi: 10.1146/annurev.en.38.010193.000331
- Howard LO (1917) A new aphid-feeding *Aphelinus*. *Proceedings of the Biological Society of Washington* 30: 77.
- Kankare M, Stefanescu C, Van Nouhuys S, Shaw MR (2005a) Host specialization by *Cotesia* wasps (Hymenoptera: Braconidae) parasitizing species-rich Melitaeini (Lepidoptera: Nymphalidae) communities in north-eastern Spain. *Biological Journal of the Linnean Society* 86: 45–65. doi: 10.1111/j.1095-8312.2005.00523.x
- Kankare M, Van Nouhuys S, Hanski I (2005b) Genetic divergence among host-specific cryptic species in *Cotesia melitaeorum* aggregate (Hymenoptera: Braconidae), parasitoids of checkerspot butterflies. *Annals of the Entomological Society of America* 98: 382–394. doi: 10.1603/0013-8746(2005)098[0382:GDAHCS]2.0.CO;2
- Kazmer DJ, Hopper KR, Coutinot DM, Heckel DG (1995). Suitability of random amplified polymorphic DNA for genetic markers in the aphid parasitoid, *Aphelinus asychis* Walker. *Biological Control* 5(4): 503–512. doi: 10.1006/bcon.1995.1060
- Kazmer DJ, Maiden K, Ramualde N, Coutinot D, Hopper KR (1996) Reproductive compatibility, mating behavior, and random amplified polymorphic DNA variability in some *Aphelinus asychis* (Hymenoptera: Aphelinidae) derived from the Old World. *Annals of the Entomological Society of America* 89: 212–220.
- Kurdjumov NV (1913) Notes on European species of the genus *Aphelinus* Dalm. (Hymenoptera, Chalcidodea), parasitic upon the plant-lice. *Russian Review of Entomology* 13: 266–270.
- Molbo D, Machado CA, Sevenster JG, Keller L, Herre EA (2003) Cryptic species of fig-pollinating wasps: Implications for the evolution of the fig-wasp mutualism, sex allocation, and precision of adaptation. *Proceedings of the National Academy of Sciences of the United States of America* 100: 5867–5872. doi: 10.1073/pnas.0930903100
- Noyes J (1982). Collecting and preserving chalcid wasps (Hymenoptera: Chalcidoidea). *Journal of Natural History* 16: 315–334. doi: 10.1080/00222938200770261



- Noyes JS (2011) Universal Chalcidoidea Database. World Wide Web electronic publication. <http://www.nhm.ac.uk/chalcidoids>
- Prinsloo GL, Naser OC (1994) The southern African species of *Aphelinus* Dalman (Hymenoptera: Aphelinidae), parasitoids of aphids (Homoptera: Aphidoidea). Journal of African Zoology 108: 143–162.
- Rincon C, Bordat D, Lohr B, Dupas S (2006) Reproductive isolation and differentiation between five populations of *Cotesia plutellae* (Hymenoptera : Braconidae), parasitoid of *Plutella xylostella* (Lepidoptera : Plutellidae). Biological Control 36: 171–182. doi: 10.1016/j.biocontrol.2005.07.018
- Rosen D (1986) The role of taxonomy in effective biological control programs. Agriculture Ecosystems Environment 15: 121–129. doi: 10.1016/0167-8809(86)90085-X
- Stouthamer R, Gai Y, Koopmanschap AB, Platner GR, Pinto JD (2000) ITS-2 sequences do not differ for the closely related species *Trichogramma minutum* and *T. platneri*. Entomologia Experimentalis Et Applicata 95: 105–111. doi: 10.1046/j.1570-7458.2000.00647.x
- Stouthamer R, Hu JG, van Kan F, Platner GR, Pinto JD (1999) The utility of internally transcribed spacer 2 DNA sequences of the nuclear ribosomal gene for distinguishing sibling species of *Trichogramma*. Biocontrol 43: 421–440. doi: 10.1023/A:1009937108715
- Timberlake PH (1924) Descriptions of new Chalcid-flies from Hawaii and Mexico (Hymenoptera). Proceedings of the Hawaiian Entomological Society 5: 395–417.
- Walker F (1839) Monographia Chalciditum. Bailliere, London, 333 pp.
- Wharton RA, Woolley JB, Rose M (1990) Relationship and importance of taxonomy to classical biological control. In: Habeck DH, Bennett FD, Frank JH (Eds) Classical Biological Control in the Southern United States. Southern Cooperative Services Bulletin No. 355, Gainesville, FL, 11–15.
- Yasnosh VA (1963) New species of the genus *Aphelinus* Dalm. (Hymenoptera, Chalcidoidea) in the fauna of the USSR. Rev Ent USSR 42: 178–189.
- Zehavi A, Rosen D (1988) A new species of *Aphelinus* (Hymenoptera: Aphelinidae) from Israel, with notes on the mali group. Israel Journal of Entomology 22: 101–108.